Natural Resource Economics
Qualifying Exam

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**Answer all of the following three questions.**

1. Suppose a perfectly competitive mining industry has a total of 10 tons of resource available. Suppose consumers' demand for this resource is described by the inverse demand curve $P = 1/\sqrt{Q}$ where $P$ is market price and $Q$ is market quantity. Suppose the interest rate is $r$. Suppose (for simplicity) that the firm incurs zero costs to extract the resource.

   State the maximization problem faced by each firm. Solve this problem. Then show that in equilibrium,

   $$Q_t = 20re^{-2rt}\,.$$

   Hint: The easiest way to do this is to assume there is only one firm. (This firm would have to be rather dumb, because it thinks it has no effect on price when actually it controls the price. Still, such a firm is possible, and you would get the same answer if you assumed the resource was equally divided among $N$ firms where $N$ is an arbitrary number.)

2. Comment in as much detail as you can on the following quotation:

   > To an engineer or scientist there is something which, if available in unlimited quantities, could, at least in principle, resolve all material resource issues. This is energy, or more properly, highly available energy of the sort released in the conversion of fossil and fissile fuels.... All industrial production processes involve the degradation of the highly available energy, obtained from fuels, to low grade heat energy. Each and every stage of production can be described in these terms... There are two features of this physical mode of description that are significant for our discussions: these are that there is a definite theoretical limit to the minimum energy input to a process and that there is no substitute for this minimum energy input...
   >
   > In the summer of 1976, an international group of economists and science-based energy analysts met in Sweden to discuss the relationship of economic and physical approaches to resource issues. Early in the meeting, it became clear that there was a deep division between the two groups. To the economists, it seemed strange to focus so much attention

on one of the inputs of production.... [Tjalling] Koopmans proposed a test which focused on the essential issue, 'What makes energy special?'...

The solution to this test, put forward by Chapman at the meeting, lay... in the non-substitutability and minimum input requirements of energy. It is possible to conceive of a process for producing iron from iron ore without any lime, or carbon, or water, or even labor—but it is impossible to affect the transformation without an input of energy. At the meeting, this exchange altered the whole approach to the issues. The economists were genuinely surprised and fascinated to know that there were thermodynamic statements that could be made that were process independent.

3. Comment in as much detail as you can on the following quotation.

... Willard Gibbs was able to show that

$$S = -k \sum P_i \ln P_i \qquad (1-3)$$

where $P_i$ refers to the energy-dependent probabilities of the various microstates.....

The Shannon equation is

$$H = -K \sum P_i \log_2 P_i \qquad (1-4)$$

where $K$ is generally taken as unity. Since proportionality constants and logarithm bases are more matters of convenience and scaling than of substance, the relationships among the variables in the two equations are identical.... The question is then whether the Shannon equation generalizes the *entropy analogues* of statistical mechanics...

While the Shannon equation is symbolically isomorphic with the Boltzmann equation, the meanings of the symbols in the respective equations have little in common....

As a result of its independent lines of development in thermodynamics and communications theory there are in science today two "entropies." This is one too many....

...there is an inevitable tendency for connotations to flow from the established to the new, and the Shannon entropy began from the beginning to take on colorations of thermodynamic entropy....

> To appreciate the importance of restricting entropy to thermodynamic applications—or, more broadly, to applications in which a macrostate-microstate relationship obtains—one need only reflect on Weaver's remarks about the Shannon formulation making contact with a universal law [the Second Law of Thermodynamics]....

Include economic applications in your discussion of this quotation.